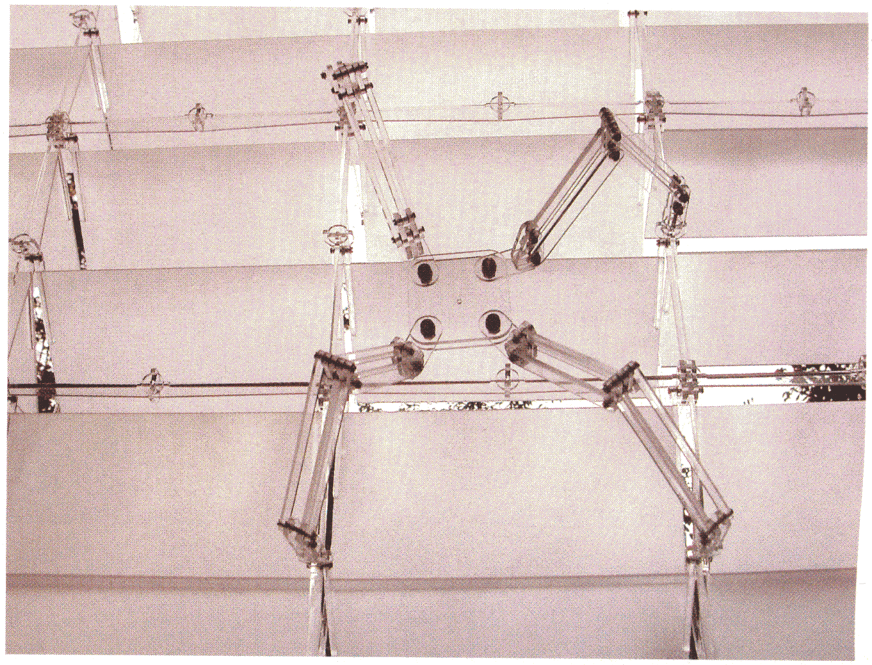
Robo Buildings: Pursuing the Interactive Envelope

IN RECENT PROJECTS, SMARTER BUILDING SKINS AUTOMATICALLY CONTROL DAYLIGHTING, VENTILATION, AND MORE TO BENEFIT OCCUPANTS AND ENHANCE SUSTAINABLE DESIGN QUALITY

By C.C. Sullivan

In an article published in the cyber journal *Technoetic Arts* last year, British architect-academics Stephen A. Gage and Will Thorne describe a hypothetical fleet of small robots they call "edge monkeys." Their function would be to patrol building facades, regulating energy usage and indoor conditions. Basic duties include closing unattended windows, checking thermostats, and adjusting blinds. But the machines would also "gesture meaningfully to internal occupants" when building users "are clearly wasting energy," and they are described as "intrinsically delightful and funny." The authors liken the relationship between edge monkey and human to that of P.G. Wodehouse's Jeeves and Wooster characters. "Jeeves's aim is always to modify Wooster's behavior so that it is more sensible," they write. "And we need all the persuasion we can get to modify our behavior before the planet is severely compromised."

Practicalities of microrobotics aside, this sci-fi-sounding scheme crystallizes the widespread concern informing many recent architectural projects. Increasingly, architects would like to automate their building envelopes rather than leave energy-efficient operation to chance (or harried maintenance engineers). As a result, the critical interface between the interior and the elements is getting more attention—and more animated.



"Edge monkeys" are robots that would close windows, check thermostats, adjust blinds, and "gesture meaningfully to internal occupants" when they are clearly wasting energy.

C.C. Sullivan is a consultant and author who specializes in architecture and technology. He is currently writing a book on interactive building envelopes.

CONTINUING EDUCATION

Use the following learning objectives to focus your study while reading this month's ARCHITECTURAL RECORD/ AIA Continuing Education article. To receive credit, turn to page 156 and follow the instructions. Another opportunity to receive Continuing Education credits in this issue can be found in the sponsored section beginning on page 163.

LEARNING OBJECTIVES

After reading this article, you should be able to:

1. *Describe interactive building envelopes.*
2. *Explain the current interest in active building skins.*
3. *Identify the application most responsible for interactive building support.*

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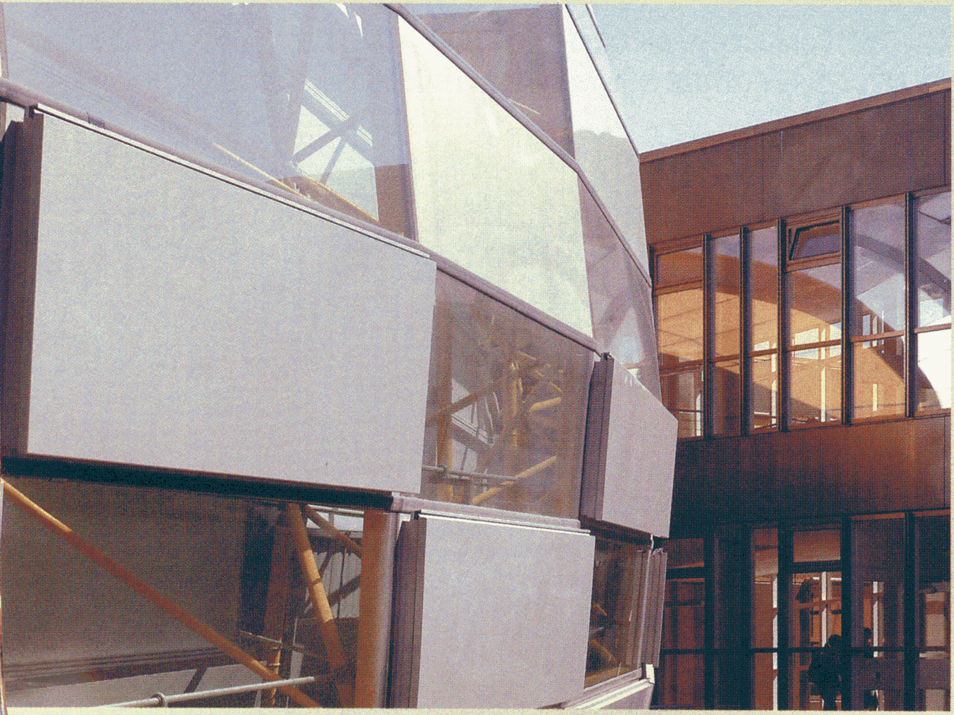
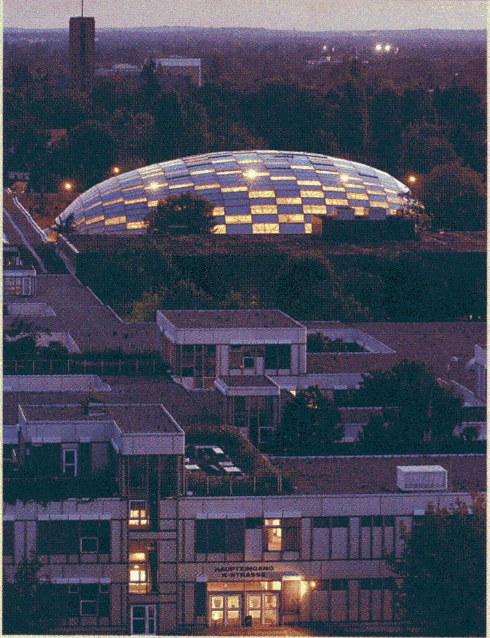
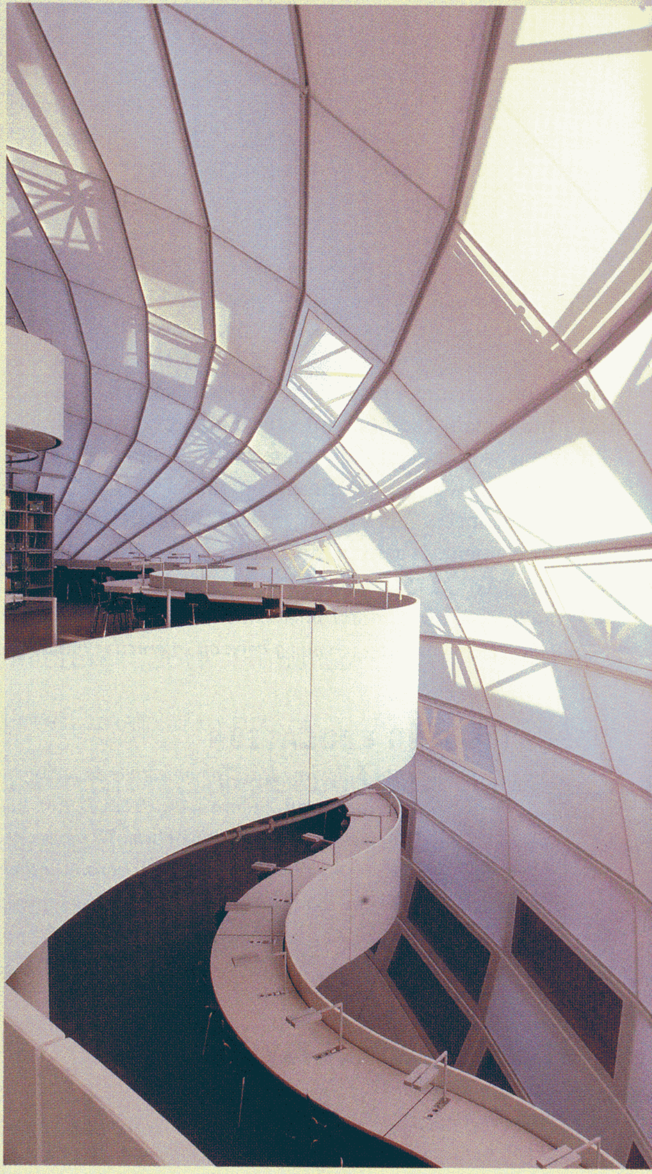
Thanks largely to innovators from Europe, buildings are wearing more smarts and moving parts. The lion's share use double-skin construction as well, in which inner and outer glass walls are separated by a ventilated cavity that often contains solar shading. Hundreds of double-glass or interactive envelopes appeared in Germany and Austria in the 1990s. In the United States, such projects are novelties, despite the existence here of an early example that debuted during the early 1980s oil crisis: Cannon's Occidental Chemical Center in Buffalo, New York, introduced a double-wall facade containing automated operable louvers.

Back then, the idea was an anomaly. Today, activating the skin is in vogue, note critics and proponents alike. From the "robotecture" labs at top architecture schools to interactive art installations like James Carpenter's *Podium Light Wall* for New York's 7 World Trade Center, aesthetics and technology are converging in unlikely places. Nonetheless, the mainstream drivers for interactive envelopes are sustainability and stringent energy codes. Another is heightened interest in "Wooster"—the end user. "The costs can't be justified strictly on the basis of energy savings," points out Eleanor S. Lee, a scientist and architect in the Building Technologies Program at Lawrence Berkeley National Laboratory (LBNL), Berkeley, California. "But these systems will be used increasingly for occupant satisfaction, including thermal comfort, acoustical performance, and access to fresh air."

While fashionable and possibly advantageous, the adoption of high-tech envelopes has been slow. Skeptical architects worry that operable components are magnets for value-engineering. Or they foresee them being unplugged and later stripped off their buildings due to poor

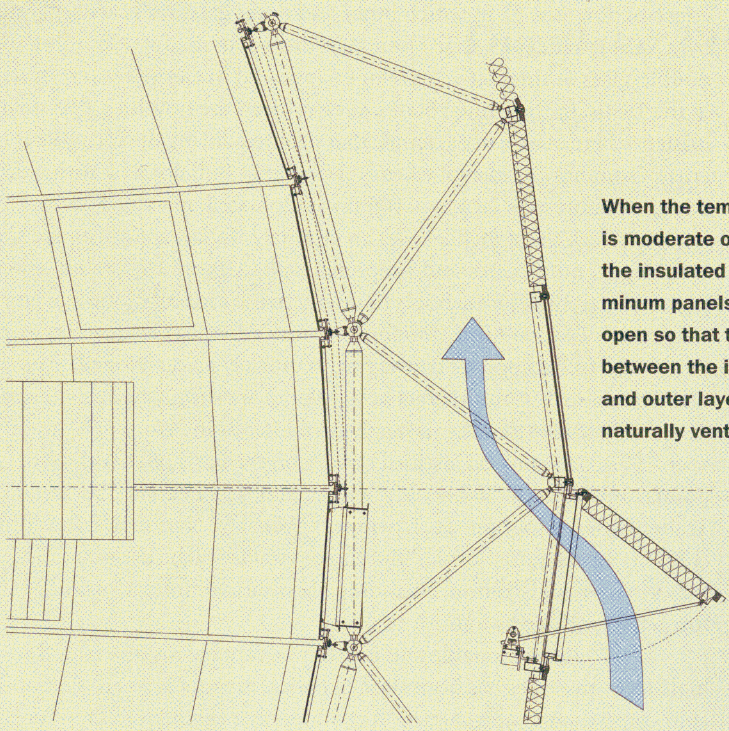






Free University Berlin

This building has an outer layer of windows and aluminum panels, and an inner layer of fiberglass fabric. In winter, warm air between the layers rises to the top, then is drawn down through the building to provide heat.



When the temperature is moderate outside, the insulated aluminum panels swing open so that the space between the inner and outer layers is naturally ventilated.

SECTION DETAIL

performance or deficient maintenance. Other firms cite client interests, noting such high-profile failures as the broken actuators on the sun-control diaphragms cladding Jean Nouvel's 1988 Institute du Monde Arabe in Paris. "Culturally, we have little confidence in what we're doing, and in systems integration for these hybrids," says Volker Hartkopf, director of the Center for Building Performance and Diagnostics at Carnegie Mellon University, Pittsburgh. "Yes, these things can break, but so can fans, dampers, thermostats, and so many other things we take for granted."

"I think such worries are well-founded," counters Bruce Nichols, a principal of the New York City–based facade consultancy Front Inc. "While an automobile maker is a single source of responsibility, that doesn't happen in architecture." He recounts his work with the Japanese firm SANAA on a competition-winning office building for the Novartis campus in Basel, Switzerland. For its transparent triple glazing with integral automated ventilation and Venetian blinds, the shades came with only five-year warranties; the glass was guaranteed for at least 10 years. So, if a shade fails after five years, Novartis would have to pay for replacing a glass unit just to access the defective shade. "We asked the manufacturers if they could get their act together to offer a collective warranty," Nichols recalls. "They couldn't."

Beyond famous failures, high installed costs, and mismatched warranties lay big coordination challenges, adds Nichols, and conflicting liabilities among project team members. Plainly, the road to the interactive envelope is a rough one. But at the end of the ride, optimal energy performance is the payoff, right? So it is hoped. Yet Lee warns there is shockingly little postoccupancy data to confirm initial design claims on older projects.

TWO THIRDS OF COMMERCIAL BUILDING COOLING LOADS COME FROM LIGHTING SYSTEMS AND SUN-LOADED GLASS SURFACES.

Sun-tracking systems lead the way

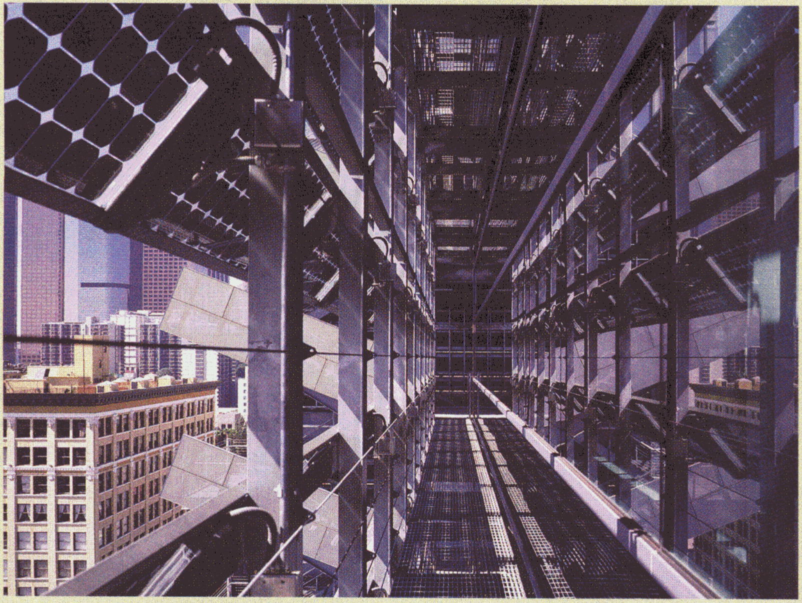
While animated as much by polemics as by actuators, new interactive envelopes still have fervent supporters. A single, conventional application gets most of the credit for the good buzz: daylighting control. On its own, an operable shade or louver is easy for an architect to analyze, especially with new daylight analysis tools built into common CAD platforms. The overarching driver for most automated shading is the typical energy profile of large commercial buildings, according to LBNL. Cooling loads dominate, with more than two thirds needed simply to counteract heat gain from lighting systems and sun-loaded glass surfaces.

Also encouraging the use of interactive envelopes is the solid performance of photosensors, dimmable lighting controls, and novel solar-tracking devices. More recent advances include switchable glazings, sometimes called "smart windows." These automatically tint or frost, activated by either an applied voltage (electrochromic) or a small release of gas, such as hydrogen (gasochromic). The former type is more widely available, but both can reduce combined cooling and lighting loads by up to 5 watts per square foot in interior perimeters.

Another appeal of automated shading relates to the feasibility of the highly transparent, relatively unarticulated building enclosures currently in fashion. For Arizona State University's Biodesign Institute in Tempe, collaborators at Gould Evans and Lord Aeck Sargent Architecture compensated for a large easterly expanse of window walls by using interior aluminum louvers controlled continuously by photocells and sun-tracking software. A manual override accessible through occupants' computers allows personal adjustments to be made.

TIMOTHY HURSLEY (THIS PAGE, MIDDLE); MARK BOISCLAIR (THIS PAGE, TOP AND BOTTOM)

Biodesign Institute, Arizona State University, Tempe A large, easterly expanse of windows uses aluminum louvers that are controlled continuously by photocells and sun-tracking software. The design allows occupants to control most of the louvers in their offices using their PCs, although at above 8 feet from floor level the louvers are controlled automatically.



Caltrans District 7 Headquarters, Los Angeles
Different elevations of the building have different systems. On the south side (above), large photovoltaic panels form a brise-soleil. On the east and west facades, perforated solar-shading screens hang a foot from the exterior wall. When they heat, air around them rises, which draws cooler air from ground level. Each day, about 1,000 screens (above right), which are located in front of windows, open and close.

Is intelligent shading worth the bother? LBNL tests suggest so. Automated daylight setups coupled with dimmable and switchable electrical lighting beat conventional fixed blinds in terms of energy draw by about a third in winter and up to 52 percent in summer. Measured daylighting levels are comparable to those for unshaded bronze glazing, with only half the solar heat gain. Lee adds that the systems allow building managers to voluntarily curtail electrical loads as part of utility demand-response programs, which help avert blackouts.

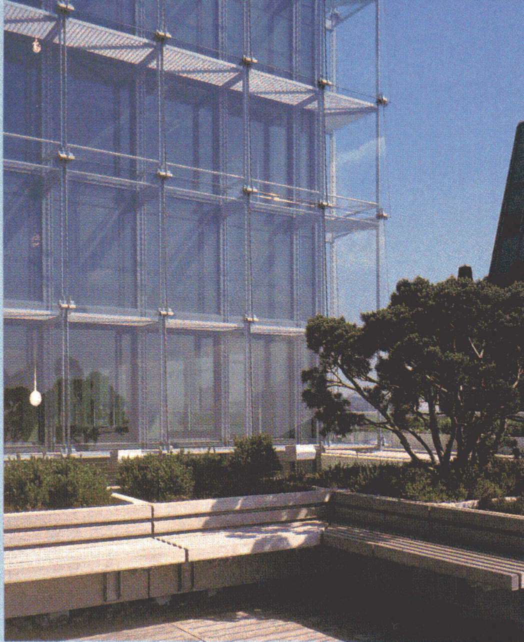
Active doubles, anyone?

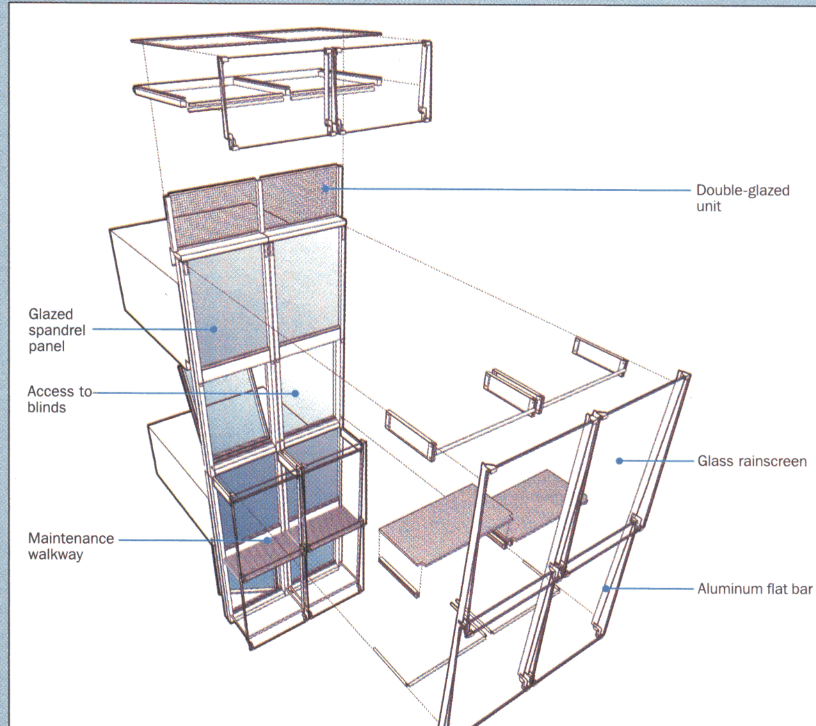
Harder to predict are the benefits of hybrid envelope systems, in which two or more interactive strategies are combined. Many European architects have integrated ventilation, shading, and other active technologies into double-wall facades that serve as primary space conditioners. Unlike Cannon's Occidental Chemical building, early double envelopes had few moving parts. (Some Europeans use the term "active facade" to describe any ventilated double wall, regardless of operability.) More recent projects feature more "edge monkeys": automated hoppers, vents, and shades.

An extreme example is the philology library by Foster and Partners at Berlin's Free University, completed last year. The four-story, orblike enclosure—with an underfloor air plenum—is engineered for free cooling for about seven months of the year using natural ventilation. A checkerboard cladding of aluminum and glazed panels protects an inner glass-fiber membrane. Operable panels close during cold weather, and fresh air is drawn from outside through the floor cavity and into the envelope void. A concrete internal structure provides thermal mass and radiant cooling and heating of recirculated air. The client expects about 35 percent energy savings over a comparable facility.

Hopefully, performance data will bear this out. But unlike Foster's 1997 energy-miser Commerzbank Tower in Frankfurt, most large-scale projects don't document utility costs. Karl Gertis, a building physics researcher at the University of Stuttgart, thinks it's because they often miss the target. In the design phase, simulations prove notoriously unpredictable, he believes. Once built, natural ventilation often isn't adequate for room air handling or for maintaining comfortable temperatures. Weak convective airflows in wall cavities may preclude the use of insect screens and air filters, too. Last, Gertis cites numerous buildings designed without mechanical cooling that have failed. Foster's library stands prepared: On hot days, it leeches supplemental cooling from an adjacent structure.

For Plantation Place, a large office development in London, Arup Associates incorporated active solar shading and occupant-controlled operable ventilation in its double-skinned cladding design. At their lower levels, the buildings have a heavy curtain of limestone fins in deference to the masonry expression of the project's Neoclassical neigh-





UPPER-LEVEL DOUBLE-SKIN CLADDING

Aurora Place, London
At the upper levels of the building, the outer layer of double-skinned facade is made up of frameless glass panels, angled at 3 degrees, with open joints. Behind the screen is a walkway used for maintenance. Tenants can open the windows to provide natural cooling. The window blinds are automatically raised or lowered based on current conditions in each tenant zone. The blinds are accessible from the outside for cleaning and maintenance.

bors. Upper levels, on the other hand, are all glass, yet those floors can be cooled with only natural ventilation during much of the year. The outer layer of the 2-foot-deep double walls comprises a rain-and-wind screen of shingled, frameless glass panels, angled at 3 degrees, with open joints. Behind it is a maintenance walkway and solar blinds adjacent to an inner window wall with operable panels. The two layers were delivered to the job site as 5-foot modules and prefabricated on-site into units with integral blinds and catwalks.

To ensure that occupants enjoyed the benefits of the complex facades, Arup Associates and facade engineers from Arup planned an unusual daylighting scheme. In each tenant zone, photosensors were mounted on inner facades to automatically control the raising and lowering of blinds based on local conditions. "There are reliability questions for automated daylighting control," admits Arup facade engineer Neil McClelland. "Any design should recognize that there will be issues and allow for access to the blinds for cleaning and maintenance." McClelland adds that the main reason to use automated blind controls is for maximum transparency, not energy-efficiency.

Stick-built robotics

For many architects, the European tradition of customizing an off-the-shelf, unitized, double-wall product presents a safe and effective entrée into the world of interactive facades. Less prevalent is the craft-based approach used by Thom Mayne for Caltrans District 7 Headquarters in Los Angeles, which opened in late 2004. There, Morphosis Architects pulled apart the envelope's functional elements, "redelegated" them, and coordinated their job-site "reassembly" among seven exterior subcontractors, says project leader Pavel Getov.

The result combines a large photovoltaic array and independently controlled, automated elements within a multiple-layer facade. The prominent shading layer of perforated metallic panels on east and west facades cuts initial solar heat gain by about 15 percent. The screen hangs about 1 foot from the slab edges of a weather-wall of metal framing, gypsum sheathing, and PVC membrane. In this way, the intervening space functions partly as convective cavity. One thousand or so of the scrim panels, corresponding to ribbon windows behind, open or close daily. Those on the east close in the morning, those on the west in the afternoon. For longevity, the architects specified stainless-steel hardware and a single pneumatic lift per panel, rather than the pair of electrical actuators originally considered. A rooftop sensor signals the panels to close during high winds.

According to Getov, 3D modeling and mock-up testing ensured the performance of the stick-built envelope under wind, rain, and seismic conditions. The firm shared a single building-information model among consultants and manufacturers, and component prototypes made on a 3D printer. Still, says Getov, "A lot of the design is resolved through the mock-ups." Even with extensive reviews and site visits for the customized, kinetic countenance, the project penciled out at $165 per square foot, including finished interiors and design fees—about the same as an average office building. The building's small facade area in relation to its floor plate accounts in part for the cost-effectiveness. Energy savings are projected at about 40 percent. Getov's advice for architects interested in the process seems counterintuitive. "The small manufacturers can be the most helpful because they don't already have a set solution in place," affording architects more conceptual control and collaboration, he explains. "It allows you to break down the process."

Omniscient control, or edge monkeys?

Beyond two ways to build a wall, the Morphosis projects also suggest two ways to make walls smart: independent control or centralized control. A project at Cooper Union in New York will integrate all facade operations into the building automation system (BAS), whereas Caltrans has independent (although Internet-accessible) envelope controls and a common override function only for emergencies, such as high winds.

Recent thinking on active envelopes mirrors that for m/e/p design generally: avoid complexity and, therefore, very integrated schemes. Some projects, such as Arup's Plantation Place , have explored highly localized automation. There, sensors mounted on the inner facade detect solar conditions for each tenant zone. Solar blinds in specified areas raise or lower autonomously, depending on the local temperature, sun strike, and occupant preferences. Natural ventilation rates are determined locally as well. Like the robotic edge monkeys, however, such islands of control need occasional global guidance—and the will to ignore the people they serve. "You can't rely on human input," says Arfon Davies, an associate with Arup Lighting in London. "And if automatic shading controls are independent from the BAS, they should still be able to send a signal to the BAS to indicate a fault."

Davies adds that even the most automated systems should have a local override. More important, says LBNL's Lee, "Windows are very much a personal item, and having that control taken away from you can be a pain. You have to have manual override." Taking a related tack, Gould Evans chose to split the control of interior blinds for Biodesign Institute. Above 8 feet from each floor, the shading is fully automated based on solar position; below that, occupants choose. "These systems begin to have a determinist impact on the psychology of the user," says Gould Evans principal Jay Silverberg. Is any optimism warranted for a new wave of smart buildings? "Architectural environments will be increasingly smart and responsive and capable of complex behaviors," predicts Michael Fox, the Venice, California–based architect and robotics expert. "Designing interactive architectural systems is not inventing, but appreciating and marshaling the technology that exists and extrapolating it to suit an architectural vision."

Edge monkeys, indeed. ■

AIA/ARCHITECTURAL RECORD CONTINUING EDUCATION

INSTRUCTIONS

- **Read the article "Robo Buildings: Pursuing the Interactive Envelope" using the learning objectives provided.**
- **Complete the questions below, then fill in your answers (page 204).**
- **Fill out and submit the AIA/CES education reporting form (page 204) or download the form at www.archrecord.com to receive one AIA learning unit.**

QUESTIONS

1. Where did double-glass or interactive-envelope buildings first appear in the early 1980s?
a. Germany
b. Austria
c. England
d. New York

2. The driving forces for interactive envelopes are all except which?
a. occupant satisfaction
b. sustainability
c. value engineering
d. stringent energy codes

3. The conventional application responsible for the fervent support of interactive envelopes by designers is which?
a. fresh-air ventilation
b. daylighting control
c. thermal-mass cooling
d. radiant cooling

4. Adoption of high-tech envelopes has been slow because architects worry about which?
a. operable components being stripped off buildings
b. stringent energy codes
c. sustainability
d. the novelty of the idea

5. The drawbacks to using interactive envelopes include all except which?
a. high installed costs
b. mismatched warranties
c. occupant satisfaction
d. famous failures

6. The typical energy profile of large commercial buildings shows what amount of the cooling load is needed to counteract the heat gain from lighting and sun?
a. one fourth
b. one third
c. one half
d. two thirds

7. Smart windows consist of which?
a. photosensors
b. dimmable lighting controls
c. switchable glazings
d. solar-tracking devices

8. The energy draw of conventional fixed blinds is beat by up to 52 percent in summer by which?
a. automated daylight setups
b. dimmable electric lighting
c. switchable electric lighting
d. a combination of all three

9. The European use of the term "active facade" describes which?
a. primary space conditioners
b. any ventilated double wall
c. edge monkeys
d. hoppers, vents, and shades

10. According to Morphosis's Pavel Getov, small manufacturers can be the most helpful to architects contemplating the robotics process for which reason?
a. they will cost less
b. they have more experience
c. they do not have a set method in place
d. they will exert more control